

WHAT IS CLAIMED IS:

1. A specification-determining method with which to determine a specification of a projection optical system used in an optical apparatus, said determining method comprising:

obtaining target information which said optical apparatus is to achieve; and

determining, based on said target information, the specification of said projection optical system with 10 using one of a wave-front aberration amount and value corresponding to a wave-front aberration, which said projection optical system is to satisfy, as a standard.

2. A specification-determining method according to 15 claim 1, wherein, in the determining of said specification, the specification of said projection optical system is determined with using as a standard the coefficient of a specific term selected, based on said target information, from coefficients of terms of a 20 Zernike polynomial in which a wave-front in said projection optical system is expanded.

3. A specification-determining method according to 25 claim 1, wherein, in the determining of said specification, the specification of said projection optical system is determined with using as a standard the RMS value of coefficients of terms of a Zernike polynomial in which a wave-front in said projection

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optical system is expanded such that said RMS value within the entire field of said projection optical system is not over a given limit.

5 4. A specification-determining method according to
claim 1, wherein, in the determining of said
specification, the specification of said projection
optical system is determined with using as standards the
coefficients of terms of a Zernike polynomial in which a
10 wave-front in said projection optical system is expanded
such that said coefficients are not over given respective
limits.

15 5. A specification-determining method according to
claim 1, wherein, in the determining of said
specification, the specification of said projection
optical system is determined with using as a standard the
RMS value, within the field of said projection optical
system, of coefficients of n^{th} order, $m\theta$ terms
20 corresponding to a watched, specific aberration out of
coefficients of terms of a Zernike polynomial in which a
wave-front in said projection optical system is expanded
such that said RMS value is not over a given limit.

25 6. A specification-determining method according to
claim 1, wherein, in the determining of said
specification, the specification of said projection
optical system is determined with using as a standard the

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RMS value, within the field of said projection optical system, of coefficients of each group of $m\theta$ terms having the same $m\theta$ value out of terms, which correspond to a watched, specific aberration, out of terms of a Zernike 5 polynomial in which a wave-front in said projection optical system is expanded such that said RMS value is not over a given respective limit.

7. A specification-determining method according to 10 claim 1, wherein, in the determining of said specification, the specification of said projection optical system is determined with using as a standard the RMS value of coefficients given by weighting according to said target information the coefficients of terms of a 15 Zernike polynomial in which a wave-front in said projection optical system is expanded such that said RMS value of the weighted coefficients is not over a given limit.

20 8. A specification-determining method according to claim 1, wherein said target information includes information of a pattern subject to projection by said projection optical system.

25 9. A specification-determining method according to claim 1, wherein said optical apparatus is an exposure apparatus which transfers a given pattern onto a substrate via said projection optical system.

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10. A specification-determining method according to
claim 1, wherein in the determining of said specification,
based on information of a pattern subject to projection
5 by said projection optical system, a simulation is
performed that obtains a space image formed on the image
plane when said projection optical system projects with
said pattern, and wherein said simulation result is
analyzed to determine a limit for wave-front aberration
10 as a standard such that said pattern is transferred
finely.

11. A specification-determining method according to
claim 10, wherein said simulation obtains said space
15 image based on linear combinations between sensitivities
of coefficients of terms of a Zernike polynomial in which
a wave-front in said projection optical system is
expanded, to a specific aberration for said pattern as a
pattern subject to projection and the coefficients of
20 terms of a Zernike polynomial in which a wave-front in
said projection optical system is expanded, said
sensitivities depending on said pattern.

12. A projection-optical-system making method with
25 which to make a projection optical system used in an
optical apparatus, said method comprising:
determining the specification of said projection
optical system according to the specification-determining

method of claim 1; and

adjusting said projection optical system to satisfy said specification.

13. A projection-optical-system making method according to claim 12, wherein, in the determining of said specification, the specification of said projection optical system is determined with using as a standard the coefficient of a specific term selected, based on said target information, from coefficients of terms of a Zernike polynomial in which a wave-front in said projection optical system is expanded.

14. A projection-optical-system making method according to claim 12, wherein, in the determining of said specification, the specification of said projection optical system is determined with using as a standard the RMS value of coefficients of terms of a Zernike polynomial in which a wave-front in said projection optical system is expanded such that said RMS value within the entire field of said projection optical system is not over a given limit.

15. A projection-optical-system making method according to claim 12, wherein, in the determining of said specification, the specification of said projection optical system is determined with using as standards the coefficients of terms of a Zernike polynomial in which a

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wave-front in said projection optical system is expanded such that said coefficients are not over given respective limits.

5 16. A projection-optical-system making method according to claim 12, wherein, in the determining of said specification, the specification of said projection optical system is determined with using as a standard the RMS value, within the field of said projection optical 10 system, of coefficients of n 'th order, $m\theta$ terms corresponding to a watched, specific aberration out of coefficients of terms of a Zernike polynomial in which a wave-front in said projection optical system is expanded such that said RMS value is not over a given limit.

15 17. A projection-optical-system making method according to claim 12, wherein, in the determining of said specification, the specification of said projection optical system is determined with using as a standard the 20 RMS value, within the field of said projection optical system, of coefficients of each group of $m\theta$ terms having the same $m\theta$ value out of terms, which correspond to a watched, specific aberration, out of terms of a Zernike polynomial in which a wave-front in said projection 25 optical system is expanded such that said RMS value is not over a given respective limit.

18. A projection-optical-system making method

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according to claim 12, wherein, in the determining of said specification, the specification of said projection optical system is determined with using as a standard the RMS value of coefficients given by weighting according to
5 said target information the coefficients of terms of a Zernike polynomial in which a wave-front in said projection optical system is expanded such that said RMS value of the weighted coefficients is not over a given limit.

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19. A projection-optical-system making method according to claim 12, wherein in the determining of said specification a simulation is performed that obtains a space image formed on the image plane when said
15 projection optical system projects with a pattern subject to projection by said projection optical system, and wherein said simulation result is analyzed to determine a limit for wave-front aberration as a standard such that said pattern is transferred finely.

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20. A projection-optical-system making method according to claim 19, wherein said simulation obtains said space image based on linear combinations between sensitivities of coefficients of terms of a Zernike
25 polynomial in which a wave-front in said projection optical system is expanded, to a specific aberration for said pattern as a pattern subject to projection and the coefficients of terms of a Zernike polynomial in which a

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wave-front in said projection optical system is expanded, said sensitivities depending on said pattern.

21. A projection-optical-system making method
5 according to claim 12, wherein said target information includes information of a pattern subject to projection by said projection optical system.

22. A projection-optical-system making method
10 according to claim 12, wherein in adjusting said projection optical system, said projection optical system is adjusted based on a result of measuring a wave-front aberration in said projection optical system so as to satisfy said specification.

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23. A projection-optical-system making method
according to claim 22, wherein said measuring of a wave-front aberration is performed before installing said projection optical system in the main body of said
20 optical apparatus.

24. A projection-optical-system making method
according to claim 22, wherein said measuring of a wave-front aberration is performed after having installed said
25 projection optical system in the main body of said optical apparatus.

25. A projection-optical-system making method

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according to claim 12, wherein said optical apparatus is an exposure apparatus which transfers a given pattern onto a substrate via said projection optical system.

5 26. An exposure apparatus which transfers a pattern formed on a mask onto a substrate via an exposure optical system, said exposure apparatus comprising:

 a projection optical system made according to the making method of claim 12 as said exposure optical system.

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27. A device manufacturing method including a lithography process, wherein in said lithography process, an exposure apparatus according to claim 26 performs exposure.

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28. A method with which to make an exposure apparatus, said method comprising:

 making a projection optical system by using the projection-optical-system making method of claim 12; and

20 installing said projection optical system in the exposure apparatus main body.

25 29. A projection-optical-system making method with which to make a projection optical system used in an exposure apparatus, said method comprising:

 adjusting said projection optical system according to exposure conditions scheduled to be used such that a best focus position in at least one point of an exposure

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area within the field of said projection optical system is displaced by a given amount, said exposure area being illuminated with exposure illumination light.

5 30. A projection-optical-system making method according to claim 29, wherein said exposure conditions include an illumination condition that a coherence factor is smaller than 0.5.

10 31. A projection-optical-system making method according to claim 29, wherein said exposure conditions include use of phase-shift-type masks.

15 32. An exposure apparatus which transfers a pattern formed on a mask onto a substrate via an exposure optical system, said exposure apparatus comprising:

 a projection optical system made according to the making method of claim 29 as said exposure optical system.

20 33. A device manufacturing method including a lithography process, wherein in said lithography process, an exposure apparatus according to claim 32 performs exposure.

25 34. A method with which to make an exposure apparatus, said method comprising:
 making a projection optical system by using the projection-optical-system making method of claim 29; and

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installing said projection optical system in the exposure apparatus main body.

35. A projection-optical-system adjusting method 5 with which to adjust a projection optical system used in an optical apparatus, said adjusting method comprising:

measuring a wave-front in said projection optical system; and

10 adjusting said projection optical system based on a result of said measuring of a wave-front.

36. A projection-optical-system adjusting method according to claim 35, wherein, in said adjusting, said projection optical system is adjusted such that the

15 coefficient of a specific term selected, based on target information, from coefficients of terms of a Zernike polynomial in which a wave-front in said projection optical system is expanded is not over a given limit.

20 37. A projection-optical-system adjusting method according to claim 35, wherein, in said adjusting, said projection optical system is adjusted such that the RMS value of coefficients of terms of a Zernike polynomial in which said wave-front within the entire field of said 25 projection optical system is expanded is not over a given limit.

38. A projection-optical-system adjusting method

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according to claim 35, wherein, in said adjusting, said projection optical system is adjusted such that the coefficients of terms of a Zernike polynomial in which a wave-front in said projection optical system is expanded
5 are not over given respective limits.

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39. A projection-optical-system adjusting method according to claim 35, wherein, in said adjusting, said projection optical system is adjusted such that the RMS value, within the field of said projection optical system, of coefficients of n 'th order, $m\theta$ terms corresponding to a watched, specific aberration out of coefficients of terms of a Zernike polynomial in which a wave-front in said projection optical system is expanded is not over a given
15 limit.

40. A projection-optical-system adjusting method according to claim 35, wherein, in said adjusting, said projection optical system is adjusted such that the RMS value, within the field of said projection optical system, of coefficients of each group of $m\theta$ terms having the same $m\theta$ value out of terms, which correspond to a watched, specific aberration, out of terms of a Zernike polynomial in which a wave-front in said projection optical system
25 is expanded is not over a given respective limit.

41. A projection-optical-system adjusting method according to claim 35, further comprising:

obtaining information of a pattern subject to projection in said projection optical system,

wherein, in said adjusting, said projection optical system is adjusted based on a space image of said pattern

5 calculated based on linear combinations between sensitivities, to a watched aberration, of coefficients of terms of a Zernike polynomial in which a wave-front in said projection optical system is expanded and the coefficients of terms of a Zernike polynomial in which a 10 wave-front measured in said projection optical system is expanded, such that said watched aberration is not over a limit, said sensitivities depending on said pattern.

42. A projection-optical-system adjusting method 15 according to claim 35, further comprising:

obtaining target information that said optical apparatus is to achieve,

wherein, in said adjusting, said projection optical system is adjusted such that the RMS value of

20 coefficients given by weighting according to said target information the coefficients of terms of a Zernike polynomial in which a wave-front in said projection optical system is expanded is not over a given limit.

25 43. A projection-optical-system adjusting method according to claim 42, wherein said target information includes information of a pattern subject to projection by said projection optical system.

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44. A projection-optical-system adjusting method according to claim 35, wherein in measuring said wave-front, a wave-front in said projection optical system is 5 measured based on a result of printing a given pattern on a wafer via a pinhole and said projection optical system.

45. A projection-optical-system adjusting method according to claim 35, wherein in measuring said wave- 10 front, a wave-front in said projection optical system is measured based on a space image formed via a pinhole and said projection optical system.

46. A projection-optical-system adjusting method 15 with which to adjust a projection optical system used in an exposure apparatus, said adjusting method comprising:

performing, when setting exposure conditions that a phase-shift mask is used with a coherence factor of smaller than 0.5 as an illumination condition, prior 20 focus correction that displaces a best focus position in at least one point of an exposure area within the field of said projection optical system by a given amount, said exposure area being illuminated with exposure illumination light.

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47. A projection-optical-system adjusting method according to claim 46, wherein said phase-shift mask is a space-frequency-modulation type of phase-shift mask.

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48. A projection-optical-system adjusting method according to claim 46, wherein said prior focus correction is implemented by adjusting an aberration in 5 said projection optical system.

49. An exposure apparatus which transfers a given pattern onto a substrate via a projection optical system, said exposure apparatus comprising:

10 a wave-front measuring unit that measures a wave-front in said projection optical system;

an adjusting unit that adjusts a state of an image of said pattern formed by said projection optical system; and

15 a controller that controls said adjusting unit using a result of said wave-front measuring unit measuring a wave-front.

50. An exposure apparatus according to claim 49, 20 wherein said adjusting unit comprises an imaging-characteristic adjusting mechanism that adjusts the imaging-characteristic of said projection optical system.

51. An exposure apparatus according to claim 50, 25 wherein said controller controls said imaging-characteristic adjusting mechanism based on a space image of said pattern calculated based on linear combinations between sensitivities, to a watched aberration, of

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coefficients of terms of a Zernike polynomial in which a wave-front in said projection optical system is expanded and the coefficients of terms of a Zernike polynomial in which a wave-front measured in said projection optical 5 system is expanded, such that said watched aberration is not over a limit, said sensitivities depending on said pattern.

52. A device manufacturing method including a 10 lithography process, wherein in said lithography process, an exposure apparatus according to claim 49 performs exposure.

53. A computer system comprising:
15 a first computer into which target information that an optical apparatus is to achieve is inputted; and
a second computer which is connected to said first computer via a communication path and determines the specification of a projection optical system used in said 20 optical apparatus based on said target information received from said first computer via said communication path with using one of a wave-front aberration amount and value corresponding to a wave-front aberration, which said projection optical system is to satisfy, as a 25 standard.

54. A computer system according to claim 53, wherein said target information includes information of a

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pattern subject to projection by said projection optical system, and

wherein said second computer performs a simulation that obtains a space image formed on the image plane when
5 said projection optical system projects with said pattern, based on said pattern information, and analyzes said simulation result to determine a limit for wave-front aberration in said projection optical system as a standard such that said pattern is transferred finely.

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55. A computer system according to claim 54, wherein said second computer obtains said space image based on linear combinations between sensitivities of coefficients of terms of a Zernike polynomial in which a
15 wave-front in said projection optical system is expanded, to a specific aberration for said pattern as a pattern subject to projection and the coefficients of terms of a Zernike polynomial in which a wave-front in said projection optical system is expanded, said sensitivities
20 depending on said pattern.

25 56. A computer system according to claim 53, wherein said optical apparatus is an exposure apparatus which transfers a given pattern onto a substrate via said projection optical system.

57. A computer system according to claim 53, wherein said communication path is a local area network.

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58. A computer system according to claim 53,
wherein said communication path includes a public
telephone line.

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59. A computer system according to claim 53,
wherein said communication path includes a radio line.

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60. A computer system comprising:
10 a first computer which is connected to an exposure
apparatus main body which transfers a given pattern onto
a substrate via a projection optical system; and
a second computer which is connected to said first
computer via a communication path, performs a simulation
15 that obtains a space image formed on the image plane when
said projection optical system projects with said pattern,
based on information of said pattern received from said
first computer via said communication path and known
aberration information of said projection optical system,
20 and analyzes said simulation result to determine best
exposure conditions.

61. A computer system according to claim 60,
wherein said pattern information is part of exposure
25 conditions that are inputted into said first computer.

62. A computer system according to claim 60,
further comprising:

a reading-in unit that reads in said pattern information recorded on a mask on a path on which said mask is transported to said exposure apparatus main body, wherein said pattern information is inputted into 5 said first computer via said reading-in unit.

63. A computer system according to claim 60, wherein said second computer sends said best exposure conditions determined to said first computer via 10 said communication path.

64. A computer system according to claim 63, wherein said first computer sets exposure conditions of said exposure apparatus main body to said 15 best exposure conditions.

65. A computer system according to claim 60, wherein said second computer obtains said space image based on linear combinations between sensitivities of 20 coefficients of terms of a Zernike polynomial in which a wave-front in said projection optical system is expanded, to a specific aberration for said pattern as a pattern subject to projection and the coefficients of terms of a Zernike polynomial in which a wave-front in said 25 projection optical system is expanded, which wave-front is obtained based on a result, sent by said first computer via said communication path, of measuring a wave-front in said projection optical system, said

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sensitivities depending on said pattern.

66. A computer system according to claim 65,
wherein said result of measuring a wave-front is inputted
5 into said first computer.

67. A computer system according to claim 65,
further comprising:

a wave-front measuring unit that measures a wave-
10 front in said projection optical system,
wherein said first computer itself obtains said
result of measuring a wave-front from said wave-front
measuring unit.

15 68. A computer system according to claim 60,
wherein said best exposure conditions include information
of a pattern suitable for exposure by said exposure
apparatus main body.

20 69. A computer system according to claim 60,
wherein said best exposure conditions include at least
one of an illumination condition for transferring a given
pattern and numerical aperture of said projection optical
system.

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70. A computer system according to claim 60,
wherein said best exposure conditions include
specification of aberration due to said projection

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optical system upon transferring said given pattern.

71. A computer system according to claim 70,
further comprising:

5 an imaging-characteristic adjusting mechanism that
adjusts the imaging-characteristic of said projection
optical system provided in said exposure apparatus main
body connected to said second computer via said
communication path,

10 wherein said second computer controls said imaging-
characteristic adjusting mechanism, based on said best
exposure conditions determined, to adjust the imaging-
characteristic of said projection optical system.

15 72. A computer system according to claim 60,
wherein said communication path is a local area network.

73. A computer system according to claim 60,
wherein said communication path includes a public
20 telephone line.

74. A computer system according to claim 60,
wherein said communication path includes a radio line.

25 75. A computer system comprising:
a first computer which is connected to an exposure
apparatus main body having a projection optical system
that projects an image of a given pattern onto a

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substrate;

an adjusting unit which adjusts a state of an image of said pattern formed by said projection optical system; and

5 a second computer which is connected to said first computer via a communication path,

wherein said second computer calculates control information with which to control said adjusting unit, using a result of measuring a wave-front in said

10 projection optical system, which result has been received from said first computer via said communication path, and

wherein one of said first and second computers controls said adjusting unit based on said control information.

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76. A computer system according to claim 75, wherein said result of measuring a wave-front is inputted into said first computer.

20 77. A computer system according to claim 75, further comprising:

a wave-front measuring unit that measures a wave-front in said projection optical system,

25 wherein said first computer itself obtains said result of measuring a wave-front from said wave-front measuring unit.

78. A computer system according to claim 75,

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wherein said adjusting unit comprises an imaging-characteristic adjusting mechanism that adjusts the imaging-characteristic of said projection optical system.

5 79. A computer system according to claim 78, wherein said first computer sends information of said pattern used in said exposure apparatus main body to said second computer via said communication path, and

10 wherein said second computer obtains a space image formed on the image plane when said projection optical system projects with said pattern by a simulation based on said pattern information and said result of measuring a wave-front, calculates a limit for a watched aberration due to said projection optical system at which said space 15 image is finely formed, and calculates control information with which to control said imaging-characteristic adjusting mechanism such that said watched aberration due to said projection optical system is not over said limit.

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 80. A computer system according to claim 79, wherein said second computer calculates a space image of said pattern based on linear combinations between sensitivities, to a watched aberration, of coefficients 25 of terms of a Zernike polynomial in which a wave-front in said projection optical system is expanded and the coefficients of terms of a Zernike polynomial in which a wave-front measured in said projection optical system is

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expanded, said sensitivities depending on said pattern.

81. A computer system according to claim 75,
wherein a plurality of sets of said exposure apparatus
5 main body and said first computer are provided, and said
exposure apparatus main bodies each have said adjusting
unit, and

wherein said second computer is connected via said
communication path to at least one of the set of said
10 plural first computers and the set of said plural
adjusting units.

82. A computer system according to claim 75,
wherein said communication path is a local area network.

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83. A computer system according to claim 75,
wherein said communication path includes a public
telephone line.

20 84. A computer system according to claim 75,
wherein said communication path includes a radio line.

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